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ERROR ANALYSIS OF UNATTENDED GROUND SENSOR OPERATORS' REPORTS.(U)

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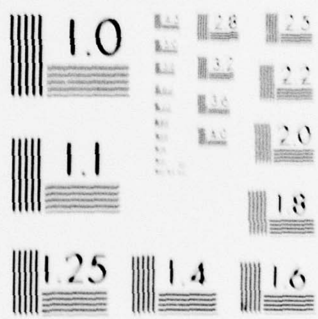

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BACKGROUND

Recent field exercises have provided unattended ground sensor (UGS) activation data from sensors employed in grid arrays. Use of grid arrays has provided increased flexibility to the UGS program, but also has created new problems.

Recent research has shown a relatively high frequency of errors committed by the UGS operator while monitoring grid arrays. The limited amount of training introduced has proven successful in improving operator performance.

However, a need for further refinement has been recognized. In order to improve grid array monitoring performance, it has been necessary to expand our knowledge concerning grid arrays and to utilize experience gained from the previous research.

The initial step in this process was an error analysis of UGS operator performance data collected from previous studies. This error analysis will help establish the goals and objectives of the training effort planned as a major project.

EARLIER PROJECTS ON UGS

The error analysis was performed on data collected from UGS operators who were participants in three previous research projects. The activation data used in all three projects was collected at Fort Bragg exercises during an April 1973 field exercise. The data consisted primarily of activations caused by military vehicles traversing a grid array sensor field one kilometer square. A brief description of those projects follows. For purposes of conciseness, these projects will be identified hereafter as project X, project Y, and project Z.

Project X[1]

This was the first of three projects conducted using the grid array. The primary objective was to compare UGS operator performance on four different monitoring displays. A total of 16 experienced operators served as subjects. The data collected from the RO-376 Tactical Data Recorder (one of the four displays tested) was analyzed in the current error analysis.

Project Y[2]

This project was conducted to determine the optimal patching technique for grid arrays on the RO-376. Four promising techniques were compared resulting in the final selection of the "Row" patching technique. A second comparison showed the 9-sensor grid array employed in a square kilometer field to be superior to the 24-sensor grid array. A total of 24 UGS operators participated in this project. Performance data from the 9-sensor grid row patching scenario segments of that project were utilized in the current error analysis.

Project Z[3]

This project utilized the 9-sensor grid, "Row" patching technique solely. Its primary objective was to compare UGS operator performance on multiple UGS monitoring displays. Three such displays, a 27-sensor display, a 54-sensor display, and 108-sensor display, were compared. Each of the 28 UGS operators participating in the project had an opportunity to monitor all three of the displays. All performance data collected on Project Z was utilized in the error analysis.

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[1] Edwards, L., Rochford, D., and Shvern, U. Comparison of Four Unattended Ground Sensor Displays. ARI Technical Paper 281, 1977.

[2] Pilette, S., Biggs, B., Edwards, L. and Martinek, H. Optimum Patching Technique for Seismic Sensors Employed in a Grid. ARI Technical Paper, 1977.

[3] Edwards, L., Pilette, S., Biggs, B., and Martinek, H. The Effect of Work Load on Performance of Operators Monitoring Unattended Ground Sensors. ARI Technical Paper, 1977.

VARIABLES

A large number of variables which could potentially affect operator performance were considered in the error-analysis. Below is a listing of variables with operational definitions, classifications, and evaluative criteria.

Target and Grid Variables.

Activity Level. The number of target patterns occurring on a 30-pen X-T plot during a given period of time. Two levels of activity were present. High activity consisted of six to eight targets within a 30-minute period; low activity consisted of two to three targets within a 30-minute period.

Noise. The presence of activations caused by sources other than valid targets. Noise was evaluated as either present or not present.

Number of Vehicles. The number of vehicles present in a target. A classification was made between a single vehicle target (e.g., one tank) and multiple vehicle target, e.g., 5 tanks.

Overlap. The degree to which the activations of one target overlap the activations of another target on the same sensor. Three levels were evaluated.

In low overlap, less than 1/3 of the target pattern was overlapped by another target pattern; in medium overlap, 1/3 to 2/3 of the target pattern was overlapped by another target; and in high overlap, from 2/3 to the whole target pattern was overlapped by another target.

Pattern Size. The length of the target pattern defined in terms of the average activation time per sensor. Three levels were identified: small - less than two minutes in duration; medium - two to four minutes in duration; large - more than four minutes in duration.

Proximity. The degree of perceived complexity when several targets activate adjacent sensors in the same row of sensors. Because there are three rows in the grid, proximity values ranged from 0 rows to 3 rows.

Sequence. The relative position of a target within a given 30-minute period. The positions ranged from first to eighth. It was assumed that target difficulty was randomly distributed.

Spacing. The degree of regularity and consistency of sensor activations within a target pattern. Three levels were defined: good - regular 10-second intervals between activations; fair - general activation uniformity with several noticeable irregularities; poor - lack of uniformity and regularity.

Target Load. The number of targets presented per given period of time. Target load was expressed in targets per hour. A range of target load levels from approximately 4 to 55 targets per hour was reviewed. Target load deals with both the number of displays and the target activity level presented to the operator.

Target Speed. The actual speed of a target. Target speeds ranged from 135 to 540 meters per minute.

Trails. The path or roadway traveled by a target. Five major trails were represented and identified as A, B, C, D, and E trails. Trails were also categorized as direct and indirect. Direct trails included trails A, C, and E. The indirect trails were B and D.

Operator Variables.

Response Requirements. Operator responses were based upon the experimental requirements. They include management of target logs, recording of target activity, and operator calculations.

Utilization of Job Aids. The degree of accuracy the operator achieved in using his job aids for time and distance measurement.

Dependent Variables.

The following four variables were used as measures of performance in the error analysis.

Detection. The reporting of an actual target. This variable was scored as either detected or not detected.

False Alarm. The reporting of a target when no target is present - an error of commission.

Target Speed. The degree of accuracy achieved in estimating the speed of a target. Two methods of scoring were utilized. One method consisted of a correct or incorrect score, based on ground truth. The second method scored the degree of deviation from ground truth in meters per minute. The second method was used to determine both absolute and relative speed deviation.

Direction. The degree of accuracy achieved in estimating the direction of travel of a given target. Two methods of scoring have been used. One method consisted of a correct or incorrect score based on ground truth. The second method scored the degree of deviation from ground truth in terms of 10 degree sectors.

RESEARCH DESIGN AND PROCEDURE

The error analysis began with the construction of a categorization of errors table. Within this table are the four dependent variables and those independent variables which potentially were considered as error-causing factors. As the analysis proceeded, some factors were removed and others were added for consideration. Table 1 shows the categorization table containing those variables which were found to be of consequence in the identification of error causing situations.

Subsequent to the construction of the table, target profiles were constructed for each of the targets presented in the three previous projects. These profiles consisted of evaluations of each target with respect to the independent variables in the categorization table.

In addition, difficulty indexes were calculated for each target with respect to the four dependent variables. This combination of difficulty indexes and target profiles made it possible to pinpoint factors related to high error situations.

The utilization of several scoring methods in the three projects plus the presence of some uncontrollable variables prevented some data from being utilized, and made statistical calculation at times unfeasible. Most of the statistics used were descriptive.

Because of the lack of adequate experimental control in respect to some variables, the use of inferential statistical methods was reduced. However, the combination of observations and calculated trends did allow the researchers to identify highly probable, error - causing situations.

Table 1. Categorization of Variables Affecting UGS Operator Performance

	Dependent Variables			
Variables	Detections	False Alarms	Direction	Speed
Activity Level				
Noise				
Number of Vehicles				
Overlap				
Pattern Size				
Proximity				
Response Requirements				
Sequence				
Spacing				
Target Load				
Target Speed (actual)				
Trails				
Utilization of Job Aids				

RESULTS

Detection Performance.

Activity Level Effects. The effects of target activity level had been shown to be substantial in all three projects. The probability of a target being detected during a period of low target activity is greater than during high target activity. Table 2 shows average target detection rates in the two activity levels of the previous three projects.

Table 2. Average Target Detection Rates

	Project			
	X	Y	Z	Overall
Low Activity	.78	.83	.74	.78
High Activity	.41	.47	.40	.43

It can be seen that targets presented during a period of relatively low target activity have a high probability of being detected. The likelihood of a missed detection or detection error is much greater during high target activity. In fact, these projects indicate that a given target is more likely missed than detected during a high target activity period.

Since increasing the activity level or intensity of a battlefield situation will lead to a greater number of missed targets, training efforts must be made to prepare the monitor for these situations. Training for better time utilization when a large number of sensors start activating would be one logical procedure.

Target Load Effects. Target load is the number of targets presented to a monitor during a given period of time. Target load is usually expressed in targets per hour. This factor is related to activity level.

However, where activity level is based on a number of targets on a given number of sensors for a 30-pen display, target load is based simply on targets per time period regardless of the number of sensors or displays an operator is monitoring.

Because of the various experimental conditions introduced, especially in Project Z, detection data is present for a good sampling of target load levels. Because variations in target load occur in different experimental situations, definitive conclusions cannot always be made, but certain trends can be pointed out with respect to detection errors.

In Table 3, the target load levels utilized in the three projects are listed in ascending order along with the target omission rates.

Table 3. Rate of Target Omission by Target Load Level

Project	Targets/Hour	Target Error of Omission Rate (Percentage)
Z	4.28	14.79
Y	4.75	17.00
X	7.75	22.00
Z	8.56	24.43
Y	12.75	53.00
Z	13.72	43.14
Z	17.12	40.21
X	20.50	59.00
Z	27.44	60.93
Z	54.88	73.43

Figure 1 presents a graphic display of the relationship between target load and the error of omission rate. The target load level has a strong effect on the error of omission rate. In the most extreme examples, with approximately four targets presented per hour, a monitor would only miss about one of every seven targets. However, when 55 targets are presented per hour, three out of every four would be missed. This data further supports the theory that the level of workload an operator faces has much to do with the number of detection errors he will make.

An important fact for any field commander to remember is that with workload being a major factor with respect to errors, a given monitor should not be placed in a position where his error rate would be expected to be unacceptably high. Anticipation of high battlefield activity and increased target workload should be reason to recruit assistance for UGS monitors.

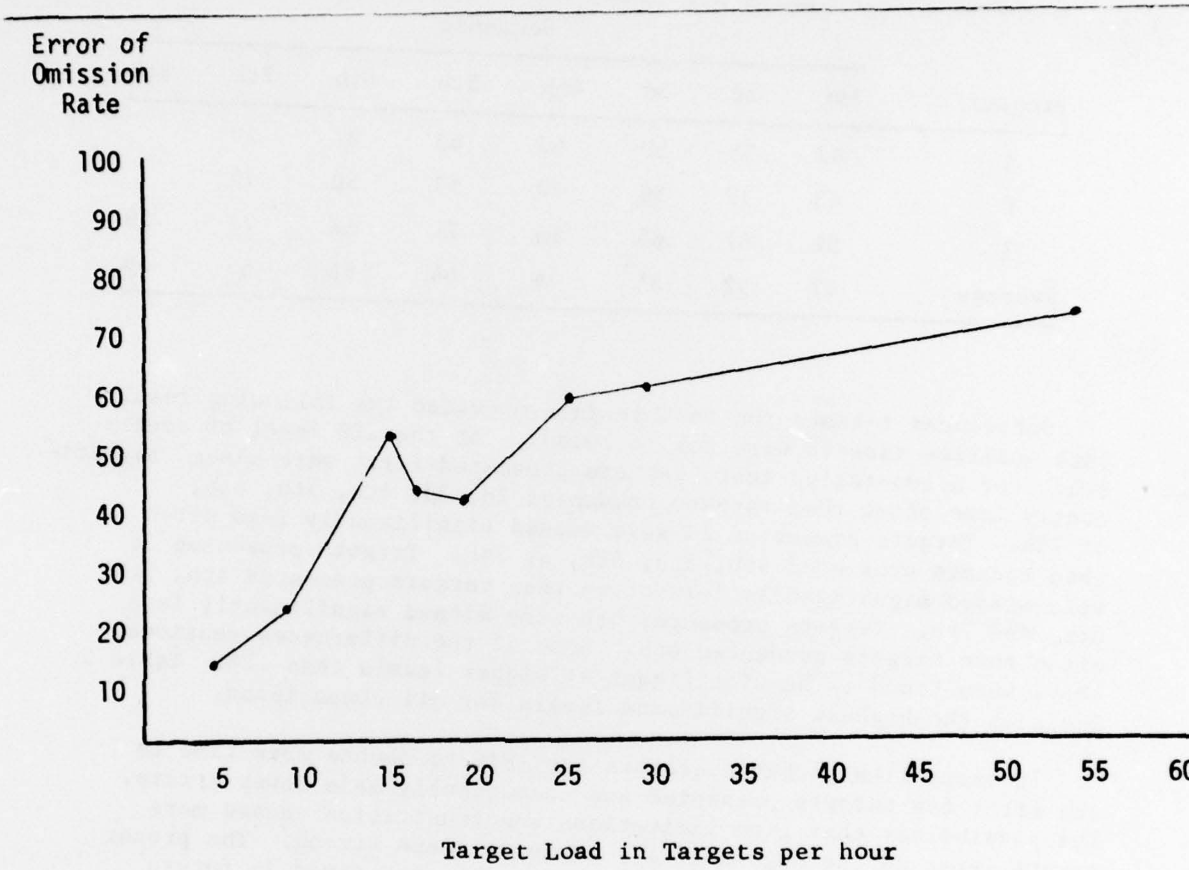

Figure 1. Error of Omission Rate by Target Load

Sequence Effects. When the three reference projects on sensor grids were conducted, the six to eight targets in high activity segments were presented in a sequential order. It was suggested that the sequential positioning of any given target might have an effect on the error rate of that target. Table 4 shows the average detection error of omission rates for targets presented in the first through eighth positions of the high activity segments.

It can be seen that the lowest overall error rates occur on the first targets presented in the segment, the next lowest rate on the second target, and the third lowest rate on the third target. The fourth through seventh targets have considerably higher error rates than the first three. The eighth target (present in only one project) shows a somewhat lower error rate.

Table 4. Error of Omission Rates (In Percent) for Target Sequence in High Activity Conditions

	Sequence							
Project	1st	2d	3d	4th	5th	6th	7th	8th
X	47	58	50	67	63	81	50	
Y	43	37	50	70	57	50	75	
Z	51	61	65	84	71	68	71	59
Average	47	52	55	74	64	66	65	59

Subsequent t-tests run on this data provided the following results (8th position targets were not included). At the .20 level of confidence for a two-tailed test, targets presented first were missed significantly less often than targets presented 2d, 3d, 4th, 5th, 6th, or 7th. Targets presented 2d were missed significantly less often than targets presented 4th, 5th, 6th, or 7th. Targets presented 3d were missed significantly less often than targets presented 4th, 5th, 6th, and 7th. Targets presented 5th were missed significantly less often than targets presented 4th. Some of the differences mentioned above were found to be significant at higher levels than .20. Table 5 includes the highest significance levels for all comparisons.

It seems likely that operators are able to devote more time to the first few targets presented and consequently made fewer errors. The possibility that time limitations and frustration caused more errors later in the high activity segments seems strong. The proper management of time and effort may need to be emphasized in future training to correct this increase in errors in the latter half of high activity segments.

This increase in errors related to target sequence did not occur in low activity situations, except for Project Z. With only two or three targets being presented, the monitors were no more likely overall to commit detection errors on the second or third target than they were on the first. Apparently, the operators had sufficient time to respond to all targets. In Project Z, where target load requirements were varied and sometimes quite high even during low activity periods, a trend did occur. For this project, the first target had a 28% error rate, the second target a 34% error rate, and the third target a 41% error rate. This phenomenon shows sequence effect due to target workload.

Table 5. Degree of Significance Between Target Sequence Positions for Error of Omission Rate

Sequence	1st	2d	3d	4th	5th	6th	7th
1st		1<2 .20 t = 1.40 df = 54	1<3 .20 t = 1.10 df = 54	1<4 .01 t = 3.18 df = 51	1<5 .05 t = 2.33 df = 50	1<6 .01 t = 2.92 df = 46	1<7 .10 t = 1.87 df = 35
2d			NS	2<4 .05 t = 2.40 df = 51	2<5 .20 t = 1.14 df = 50	2<6 .10 t = 1.69 df = 46	2<7 .20 t = .97 df = 35
3d				3<4 .05 t = 2.19 df = 51	3<5 .20 t = 1.36 df = 50	3<6 .10 t = 1.91 df = 46	3<7 .20 t = 1.13 df = 35
4th					4>5 .20 t = .72 df = 47	NS	NS
5th						NS	NS
6th							NS

NS = Non-Significant

Under the experimental condition in which operators monitored 12 sensor grids during project Z, the target load level for low activity was higher than 17 targets per hour. This high target load level seems to have caused operators difficulty in keeping up with the targets as they were presented, thus causing an increase in the error of omission rate for those targets presented later in the 30-minute segments.

Trail Effects. The sensor grid data was collected at Fort Bragg in 1973 in a field area containing five basic trails. Almost all targets traveled on one of these trails. Figure 2 shows the grid with the five trails. Trails A, C, and E are basically straight line trails running directly from the top to the bottom of the grid, compared with trails B and D which are somewhat longer winding, indirect trails which run diagonally through or circumvent the sensor grid. The distinction between the two groups of trails is quite pronounced and it was felt that the error rates associated with the two might be somewhat different. For purposes of classification, trails A, C, and E were denoted as direct trails and trails B and D as indirect trails. An error analysis on direct and indirect trails for both activity levels in all three studies was conducted and the summarized results are presented in Table 6. Of particular interest in Table 6 are the error rates for low activity segments. In all three studies, the error rates in the low activity segments were greater for targets traveling direct trails than for targets traveling indirect trails. During high activity this difference in error rates was not found. One explanation for this differential comes from viewing the X-T plots of low activity segments. Generally, those targets traveling indirect routes activate a larger number of sensors; because the trails are longer, activations occur over a longer time period. This longer, more extensive activation pattern would logically lend itself to detection better than a shorter pattern involving fewer sensors.

In high activity situations, a larger, more extensive pattern would not be necessarily advantageous for detection because of the relatively high amount of activation congestion and target overlap.

In low activity, it would appear that operators tend to overlook targets on the shorter, more direct trail. This is an error situation which should be corrected. Future training should emphasize the equal importance of targets, and caution against overlooking smaller activation patterns.

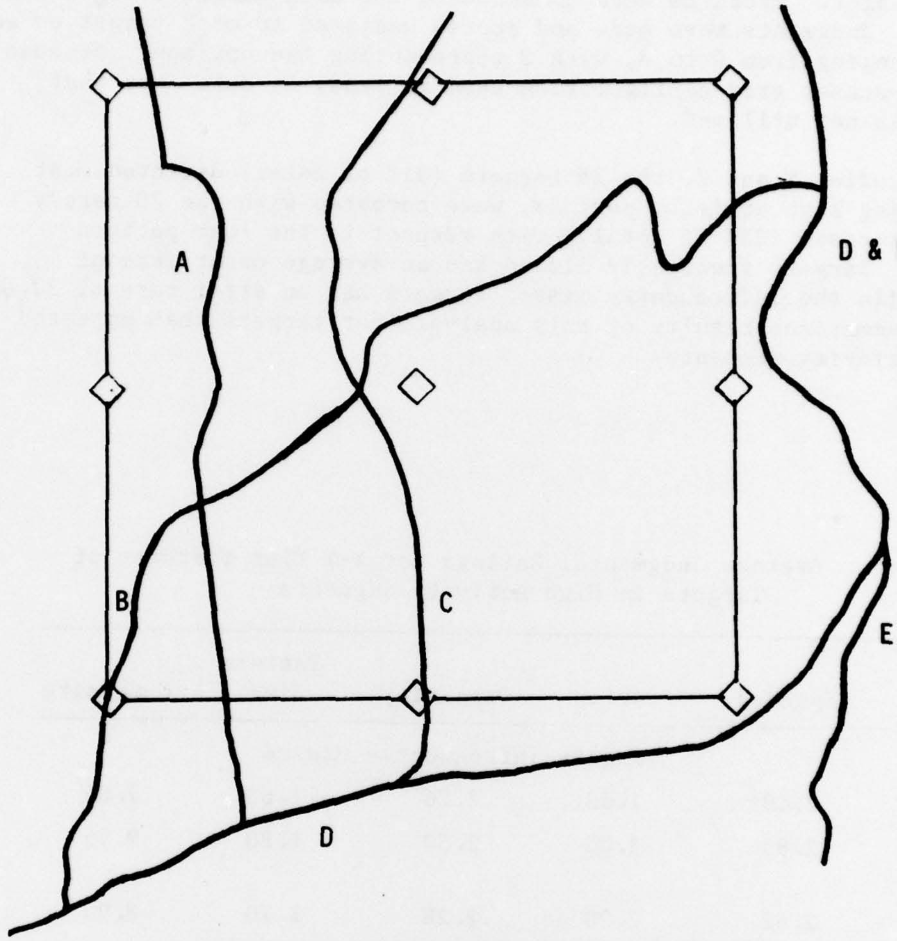

Figure 2. Nine-sensor Grid with Ground Truth Trails

Table 6. Error of Omission Rates (In Percent) for Targets by Trails

	Direct Trails			Indirect Trails		
Project	Low Activity	High Activity	Combined	Low Activity	High Activity	Combined
X	26	53	46	17	69	53
Y	26	51	44	13	58	44
Z	34	74	63	28	58	51
Average	29	59	51	19	62	49

X-T Plot Features Effect. Spacing, overlap, proximity, and pattern size are four important features of the target patterns as they appear on an X-T plot. Profiles were constructed for each target using these features. Judgments were made and scores assigned to each target on each feature ranging from 0 to 3, with 3 representing the optimum. Because of the 24-sensor grid configuration used in study X, data from that project was not utilized.

For studies Y and Z, the 25 targets (31% of total) detected most often during high activity periods, were compared with the 20 rarely detected targets (25% of total), with respect to the four pattern features. Targets frequently missed had an average error rate of 91.6%, while the infrequently missed targets had an error rate of 27.0%. Table 7 summarizes results of this analysis for targets that appeared in high activity segments.

Table 7. Average Judgmental Ratings for X-T Plot Features of Targets in High Activity Segments

	Spacing	Overlap	Proximity	Pattern Size	Composite
			Targets Infrequently Missed		
Study Y	2.40*	1.60	2.26	1.60	7.86
Study Z	2.85	3.00	2.30	1.80	9.95
Overall Mean	2.62	2.30	2.28	1.70	8.90
			Targets Frequently Missed		
Study Y	1.50	1.20	2.30	1.20	6.15
Study Z	1.35	2.40	1.30	.75	5.80
Overall Mean	1.42	1.80	1.80	.97	5.97

Note. Features judged on 0-3 scale where 3 is optimum.

All four X-T plot features were generally rated higher on the infrequently, rather than the frequently, missed targets. Individually, each feature may well have had a causal relationship to detection errors. Together as a composite, there is even a stronger likelihood of an error effect during high target activity. T-tests run on the X-T plot features showed spacing ($t = 5.08$, $df = 43$) and pattern size ($t = 2.48$, $df = 43$) scores to be significantly higher (.01 level) for infrequently missed targets. Overlap ($t = 1.20$, $df = 43$) and proximity ($t = 1.51$, $df = 43$) scores were also significantly higher (.20 level) for infrequently missed targets.

Table 8 shows the results for targets that appeared in low activity segments. In low target activity, the total composite scores for infrequently missed targets were higher than the total composite scores for frequently missed targets. In low activity, however, the differential was primarily due to two of the X-T plot features, spacing and pattern size.

Table 8. Average Judgmental Ratings for X-T Plot Features of Targets in Low Activity Segments

	Spacing	Overlap	Proximity	Pattern Size	Composite
		Targets Infrequently Missed			
Study Y	2.00*	3.00	3.00	2.00	10.00
Study Z	1.80	3.00	3.00	2.40	10.20
Overall Mean	1.90	3.00	3.00	2.20	10.10
		Targets Frequently Missed			
Study Y	1.50	3.00	2.33	.50	7.33
Study Z	1.50	3.00	3.00	1.50	9.00
Overall Mean	1.50	3.00	2.67	1.00	8.17

Note. Features judged on 0-3 scale where 3 is optimum.

The irregular and inconsistent spacing of sensor activations was more common in targets with high error rates, and, in general, the size of the patterns was smaller. T-tests showed pattern size ($t = 2.01$, $df = 20$) and spacing ($t = 1.02$, $df = 20$) scores for infrequently missed targets to be significantly higher than scores for frequently missed targets. The significance levels were .10 and .20 respectively.

Spacing and pattern size yielded similarly low results in both the high and low activity situations. The noticeable difference in the high activity condition, however, is that proximity and overlap appear related to detection errors. The patterns show that both these variables are functions of the presence of other target patterns which are either close to or converging on the monitored target. In low activity situations proximity and overlap are not problems because of relative sparsity of targets present. Emphasis on these four features for training purposes could prepare operators for many eventualities in the field.

A unique example of high error-causing situations occurred in project Z in one of the low activity 30-minute segments. A target presented at the end of the 30-minute segment was preceded by only one other target at the beginning of the segment. The target activated two sensors for a short period of time, and the pattern was clear with no noise activations or other target activations. None of the 28 monitors detected this target. The target which preceded it was detected by 79% of the operators. It must be deduced that a certain amount of inattentiveness and low motivation was at least partially responsible for errors of this kind. Future training and follow-up testing must make attempts at preventing situations such as this from recurring.

Target Direction Deviation.

The task of tracing the path of a target to determine direction was a major objective of operators in all three of the projects. This task was particularly challenging because of inherent differences in grid employment and the conventional sensor string employment.

The operators who participated in the projects were experienced in the monitoring of strings along roadways in which target direction could be determined easily. Use of the grid did not require that sensors be employed on or near roadways. In the three projects referenced, sensors were placed in an area through which targets might travel in any direction. Consequently, determining where a target in fact did travel became considerably more difficult.

In project X, operator's direction responses were scored as either correct or incorrect. In studies Y and Z, the scoring techniques was revised to a direction deviation basis. An operator's estimate of direction was evaluated in terms of the number of 10° sectors that estimate deviated from ground truth.

Number of Vehicles Effect. In the attempt to determine what factors contributed to errors in direction determination, composition of the targets was reviewed. A large number of combinations of military vehicles had been utilized. A major distinction between two groups of targets was single vehicle targets and multiple vehicle targets. During high activity periods, an approximately equal number of both groups was used. Unfortunately, in low activity periods there was not a sufficient number of single vehicle targets to conduct an error analysis. An analysis was performed on targets in high activity periods in study Y and study Z. The results are summarized in Table 9. For both studies, operators were better able to determine the direction of single vehicle targets. A t-test showed that direction deviation scores were significantly lower (.20 level) for single vehicle targets ($t = 1.15$, $df = 72$).

Table 9. Direction Deviation for Single Versus Multiple Vehicle Targets by 10° Sectors in High Activity Segments

Project	Single Vehicle	Multiple Vehicle
Y	4.0	4.6
Z	4.5	5.5

The reason why multiple vehicle targets would cause monitors to misinterpret direction is not totally clear. By looking at a target as it would appear on an X-T plot, one can see a possible explanation. In Figure 3, activations are caused by a single vehicle target traveling between two sensors (2 and 3). On sensors 11 and 12, the activations are caused by a multiple vehicle target. The two sensor maps show the ground truth path of the target and the operator's response to the target. In Figure 3, notice that the heavier activation pattern caused by the multiple target caused the monitor to trace the target path very near the sensors. In the single target case, the monitor was not as strongly oriented this way because the activation patterns are shorter and less intense. It seems that longer, more intense activation patterns frequently cause monitors to focus more upon target sensor proximity than upon the notion of multiple targets.

A second and perhaps more important consideration is the fact that in high activity segments, a target creating more sensor activations is far more likely to have its target pattern overlap or be in close proximity to other target patterns, again causing more problems for the UGS monitor.

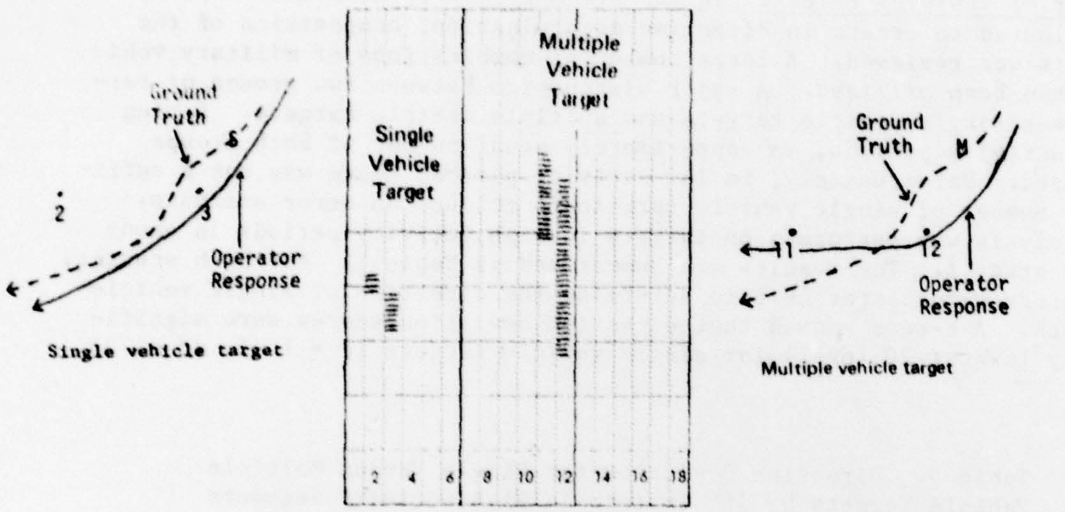

Figure 3. X-T Plot and Maps of Single and Multiple Vehicle Targets

Both types of miscalculations can be corrected through adequate training. First, monitors should be instructed to concentrate on proportional relationships between numbers of activations in determining the location of targets rather than attending to absolute numbers as they do when making other calculations. Second, training must be provided which will enable monitors to better isolate one target pattern from another.

Trail Effects. As discussed previously, the trails that targets traveled in these studies were classified under two headings, direct or indirect. The direct routes were relatively straight paths which crossed the sensor field from top to bottom. The indirect routes were paths that traversed the field diagonally or circumvented it, and thus were somewhat longer than the direct routes.

Table 10 shows the average direction deviation scores for targets traveling direct and indirect trails presented in both activity levels of projects Y and Z.

Table 10. Direction Deviation Scores (10^{o} Sectors) of Targets on Direct and Indirect Trails

	Target Activity	Direct	Indirect
Project Y	High	3.0	6.2
	Low	3.8	3.1
Project Z	High	4.5	5.1
	Low	4.2	3.7

A t-test analysis indicated that during high activity periods, target direction was determined more accurately on targets traveling direct rather than indirect routes. This difference was significant at the .01 level ($t = 3.01$, $df = 69$).

However, during low activity periods, direction may have been more accurately assessed for targets traveling the indirect routes. This difference was significant at the .20 level ($t = .79$, $df = 23$).

In reviewing the X-T plots which the subjects monitored, it was noted that in high activity segments, parts of the longer indirect routes were frequently overlooked by monitors or mistakenly combined with parts of other targets. Thus when a measure of direction was calculated, there was a relatively high frequency of errors. Targets with more direct routes were less susceptible to this type of error.

In low activity conditions, the larger indirect route targets were not likely to be confused with other targets. In fact, the longer routes which involved more activations on more sensors actually lent themselves to more proficient direction determination than did the targets traveling shorter routes with subsequent smaller target patterns. Thus, direction errors tended to occur more frequently on direct route targets during low target activity.

The errors developed from inaccurate monitoring of activations on the various sensors involved. Operators must be trained to separate accurately the activations from more than one target during heavy target activity. Also, techniques for accurate direction determination should be taught for those cases where direct routes of targets cause a relatively small number of activations.

A tendency on the part of operators to interpret activations within the rows of the grids as though they were strings was noticed in project X. Training sessions in projects Y and Z stressed the avoidance of this type of error which led to both false alarms and errors in determining target direction. This training was generally successful. However, this type of error still was committed in Y and Z. Future training should place increased emphasis on the uniqueness of the sensor grid arrangement to counteract the effects of previous training with sensor strings.

Target Speed Deviation.

Activity Level Effects. Target speed in project Z was underestimated on the majority of targets in both high and low activity periods. This underestimation of speed is a phenomenon which appears to occur frequently with grid but infrequently with sensor string data. It has been deduced that speed underestimation is a function of the sensor grid employment technique and will occur regardless of activity level. The monitor's tendency to equate a sensor activation with a target located on or near the sensor, rather than simply within its detection range, is believed partially responsible for this type of error.

Number of Vehicles Effect. One other factor which appeared to increase the target speed error rate was the single vehicle target condition. An analysis conducted on absolute speed deviation for projects Y and Z, and on relative speed deviation in project Z showed a greater tendency for error when operators monitored a single vehicle target, than when they monitored a multiple vehicle target. These results are summarized in Table 11. The results are all from high activity periods because of the scarcity of single vehicle low activity targets.

Table 11. Speed Deviation on Single and Multiple Vehicle Targets in Meters/Minute

		Single Vehicle Targets	Multiple Vehicle Targets
Project Y Absolute Speed	High Activity	89	76
Project Z Absolute Speed	High Activity	114	97
Project Z Relative Speed	High Activity	-77	-23

The great number of activations usually present in a multiple vehicle target pattern activation, may provide a slightly more consistent base for calculating the time measurements necessary for speed calculations.

The errors made with regard to single vehicle targets might be corrected best through training of accurate time measurements on targets having a relatively small number of sensor activations.

In reviewing the X-T plot papers and response sheets completed in the referenced projects, it was noted that errors were occasionally made in the measurement and reporting of time and distance. These errors were more common during high activity and high target load situations.

Although training time was spent on the proper use of the UGS ruler, it appears that a stronger emphasis, perhaps through repetitive practice, should be placed on proper measurement of time and distance.

False Alarms.

Each of the three projects was scored for false alarms, i.e., errors of commission. The rate of reported false alarms was relatively low for projects Y and Z, however, project X results did show a considerably higher false alarm rate. This higher frequency of false alarms may have been partially the result of the less extensive grid training provided in project X.

The utilization of a sensor grid appeared to confuse monitors in project X more so than in subsequent projects. Project X operators tended to react as if the sensors were placed in strings along trails (as discussed previously). Consequently, operations tended to report a large number of false alarms. Increased training was provided in projects Y and Z to lower the false alarm rate; this goal was achieved.

<u>Activity Level Effects</u>. Of the false alarms reported in project Y and Z, more occurred during low than high activity periods. A decrease in false alarms also occurred as the target load level increased. This false alarm effect is the opposite of the detection error (error of omission) effect which increases during high activity and high target load periods and decreases during low activity and low target load periods. Table 12 shows the false alarm rates for the three projects.

Table 12. False Alarms Per 100 Targets Presented

	HIGH Activity	LOW Activity
Project X	23	54
Project Y	1	9
Project Z	1	4

The substantial decrease in false alarms in projects Y and Z is probably due to the additional grid training mentioned previously. Future training should concentrate on elimination of false alarms during low activity periods.

During those periods, perhaps monitors have the time to attend to small groups of activations, and mistakenly report them as targets. Emphasis should be placed on identification of various noise, weather, animal and aircraft activation patterns so that such signals will not be interpreted as valid targets.

General Errors.

A factor causing errors on all dependent variables in the three previous projects has been the coordination of target logs. Specific problems were unique to each project but the general type of error occurred in all three.

In project X, two sensor fields were monitored simultaneously. Different color response sheets (target logs) were assigned to each field. However, targets on one field were at times reported on the inappropriate target log. This problem was confounded by occasional inaccurate identification methods used by the operators.

In project Y, operators alternately monitored two sensor fields, one of which contained nine sensors and the other 24 sensors. Again, mix-ups occurred; some targets were reported on the wrong target logs.

In project Z, this entire problem was magnified by the utilization of as many as 12 sensor fields simultaneously. Occurrence of errors in this situation was high. In some cases, operators seemed to disregard correct identification procedures entirely.

This kind of mismanagement of target logs and report sheets could cause serious problems in a field situation. Certain experimental situations which were devised did require a good deal of organization on the part of the operator. However, similar situations possibly could arise in the field as well.

Successful training should emphasize the importance of proper target identification and recording. Examples of excellent monitoring skills coupled with poor recording documentation and the possible consequences should be offered.

SUMMARY OF RECOMMENDATIONS

Analysis of errors committed in the three projects utilizing the sensor grid array has shown that certain situations do appear to increase the likelihood of monitor errors. It is, of course, impossible to eliminate all error from the monitoring task, but certainly appropriate training geared to the objective of reducing the frequency of errors should be developed.

To help develop an improved training program, a number of recommendations have been made regarding the various errors uncoverd in this analysis. A summary of these errors with recommendations for corrective measures is submitted below.

The effect of increased target activity and target load on detection errors of omission is crucial. As either increases, so does the rate of detection errors. The time and effort requirements plus the increase in visual stimuli make for a more difficult task. Future training must make efforts to assist operators in coping with more intense battlefield conditions.

Low target activity and low target load conditions also contribute to error situations but more frequently errors are in the form of false alarms. False alarm errors do not appear as serious in terms of frequency as errors of omission. However careful study of questionable activation patterns should be encouraged.

The effects of single and multiple vehicle target patterns on speed and direction estimation points to the need for closer examination of activations on the X-T plot. Examples of activations of various combinations of vehicles with tips for differentiation should be included in future training.

he use of comparative examples should also prove helpful in dealing direct and indirect target trails. This type of error seems to be ction of grid array. An emphasis on the important differences in ation patterns on the grid as compared to the string is necessary. approach should also help minimize the amount of speed underestima- which consistently appeared in Project Z. The only other alter- e would be acceptance of underestimation on the grounds that indi- travel of vehicles on the grid causing underestimation is completely rstood by field commanders. Although the operators are not reporting true target speed they are reporting the crosscountry speed and this d is important in helping to determine how far the target will travel t maintains the same route mechanics.

Occurrence of errors associated with sequence of presentation of the et, plus other unexplainable errors on certain targets points to need for maintaining vigilance and attention on the part of the rators. Operators should be prepared to handle the increased level confusion and ambiguity which sometimes occur.

X-T plot pattern features which appeared to contribute to the ber of errors included high proximity to other target activations, ll target pattern size, high target overlap, and irregular activation cing. Variations in these features are, of course, caused by varia- ons of events occurring in the sensor field; however, it is felt that ling with the X-T plot features directly can be useful for training rposes. Combinations of a large number of possible variations of se factors could be presented to operators as exercises. Those which e more frequently associated with errors should receive the greatest ncentration and emphasis.

A significant error-causing factor involves the combination of errors f measurement, calculation and response requirement management. These perator responsiblities have been emphasized in previous training pro- rams, but it appears that renewed emphasis and re-emphasis is necessary.

INCORPORATION OF RESULTS INTO TRAINING PROGRAM

The identification of error-causing factors in this analysis should e helpful in creating a basis for the proposed training. Recommen- lations have been offered with respect to particular kinds of errors. The use of these recommendations in addition to previously established training exercises for sensor grids should provide a sound orientation to UGS operators. The ultimate result should be improved operator performance.

The use of comparative examples should also prove helpful in dealing with direct and indirect target trails. This type of error seems to be a function of grid array. An emphasis on the important differences in activation patterns on the grid as compared to the string is necessary. This approach should also help minimize the amount of speed underestimation which consistently appeared in Project Z. The only other alternative would be acceptance of underestimation on the grounds that indirect travel of vehicles on the grid causing underestimation is completely understood by field commanders. Although the operators are not reporting the true target speed they are reporting the crosscountry speed and this speed is important in helping to determine how far the target will travel if it maintains the same route mechanics.

Occurrence of errors associated with sequence of presentation of the target, plus other unexplainable errors on certain targets points to the need for maintaining vigilance and attention on the part of the operators. Operators should be prepared to handle the increased level of confusion and ambiguity which sometimes occur.

X-T plot pattern features which appeared to contribute to the number of errors included high proximity to other target activations, small target pattern size, high target overlap, and irregular activation spacing. Variations in these features are, of course, caused by variations of events occurring in the sensor field; however, it is felt that dealing with the X-T plot features directly can be useful for training purposes. Combinations of a large number of possible variations of these factors could be presented to operators as exercises. Those which are more frequently associated with errors should receive the greatest concentration and emphasis.

A significant error-causing factor involves the combination of errors of measurement, calculation and response requirement management. These operator responsiblities have been emphasized in previous training programs, but it appears that renewed emphasis and re-emphasis is necessary.

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A suggested framework for the training program would initially include a review of key topics dealing with basic UGS target detection and readout procedures for the solitary target case.

This phase of the training would use fundamental subject matter content with some refinements resulting from recent research. An analysis of grid employment patterns would be presented with the inclusion of information about target-related errors and X-T plot features, e.g., size, shape, etc.

The second major portion of the training should deal with more complex target cluster situations involving target activity and operator management responsibility, including multi-display monitoring techniques and sensor data problems. Results of the present analysis plus information gleaned from recent field-training exercise experience will be utilized to complete this phase.

This program should be offered in a workbook using an individualized, self-paced approach and, if possible, a lecture/Vu-graph presentation of the target cluster situations. The vu-graphs should maintain attention and promote learning. A balanced combination of student participation with instructor guidance, when necessary, should help insure a successful training package.